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(54) **ADAPTIVE MOTION CONTROL FOR CARRIAGE PRINTER**

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B41J 23/00 (2006.01)
B41J 29/393 (2006.01)

(52) **U.S. Cl.**
USPC **347/37**; 347/19

(58) **Field of Classification Search**
CPC B41J 2/19
USPC 347/12, 19, 20, 37, 101, 104
See application file for complete search history.

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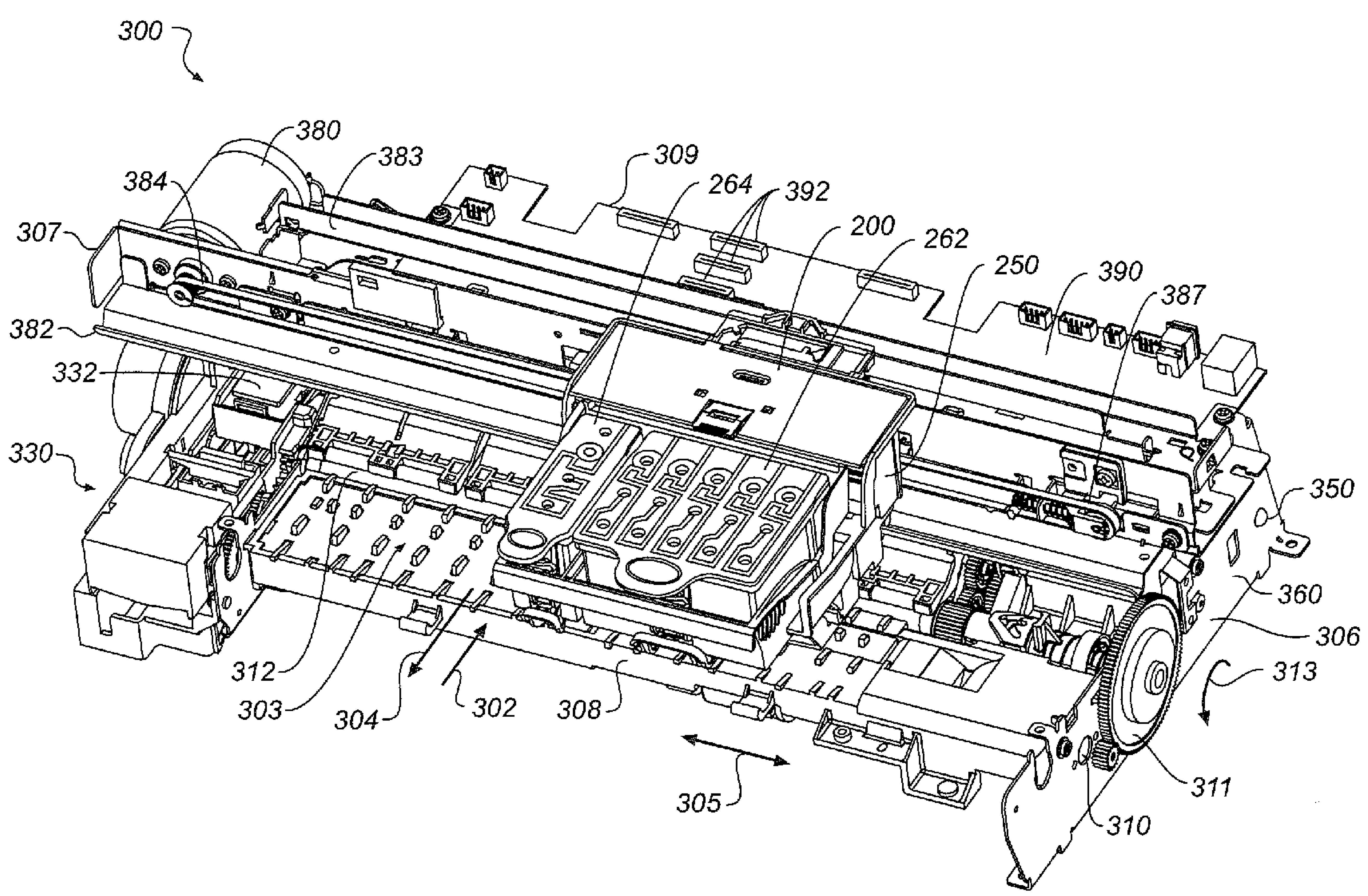
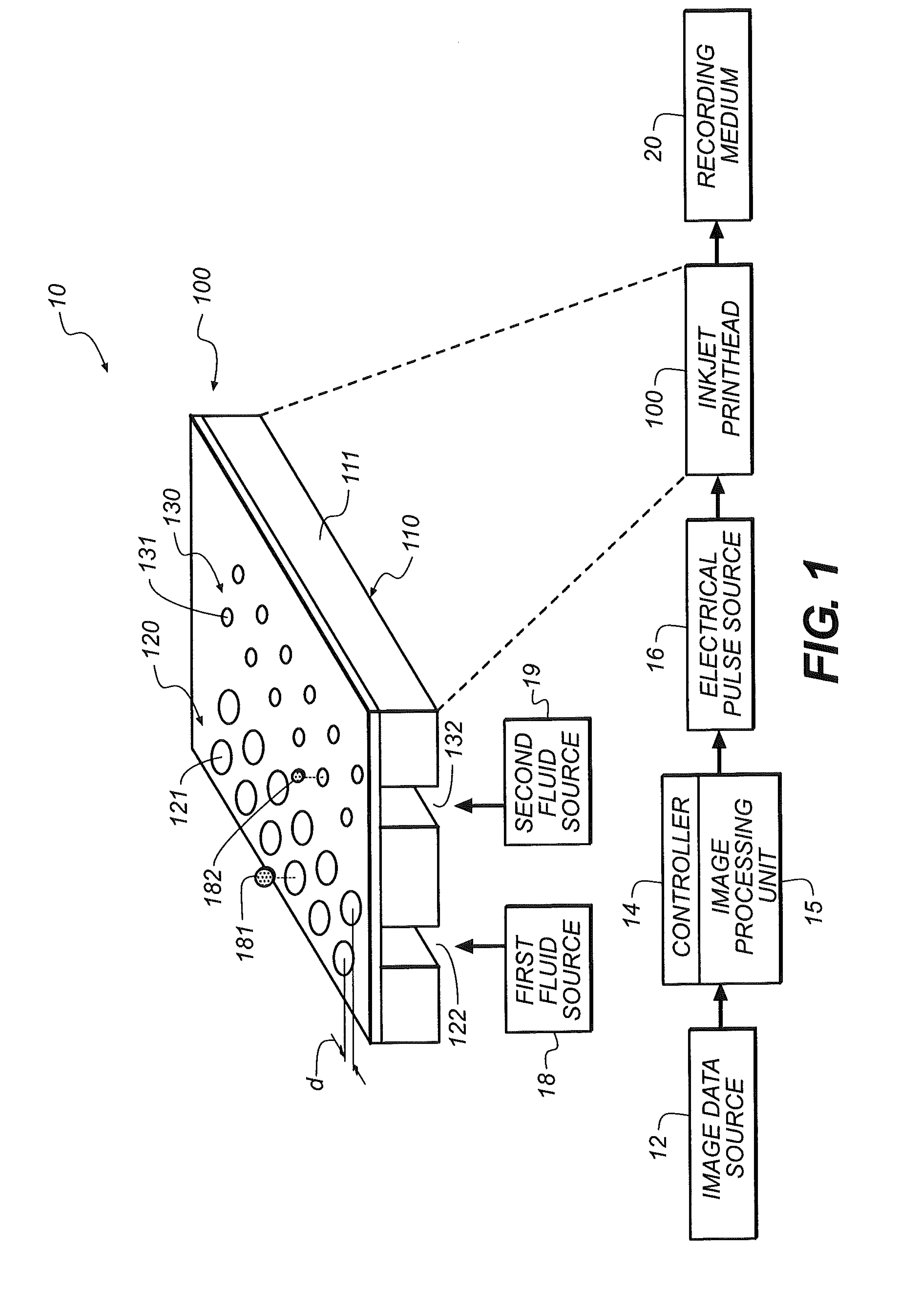
(57) **ABSTRACT**

A method of adaptively controlling motion of a carriage in a carriage printer within a user's environment, the method includes controlling a motor to move a carriage of a carriage printer within a user's environment according to a first motor control profile; acquiring data relative to a motion of the carriage printer as the carriage is moved according to the first motor control profile; analyzing the acquired data relative to the motion of the carriage printer corresponding to the carriage being moved according to the first motor control profile; and controlling the motor to move the carriage of the carriage printer according to a second motor control profile.

20 Claims, 9 Drawing Sheets

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SECOND FLUID SOURCE
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FIRST FLUID SOURCE
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IMAGE DATA SOURCE
14
CONTROLLER
IMAGE PROCESSING UNIT
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16
ELECTRICAL PULSE SOURCE
100
INKJET PRINTHEAD
20
RECORDING MEDIUM

FIG. 1

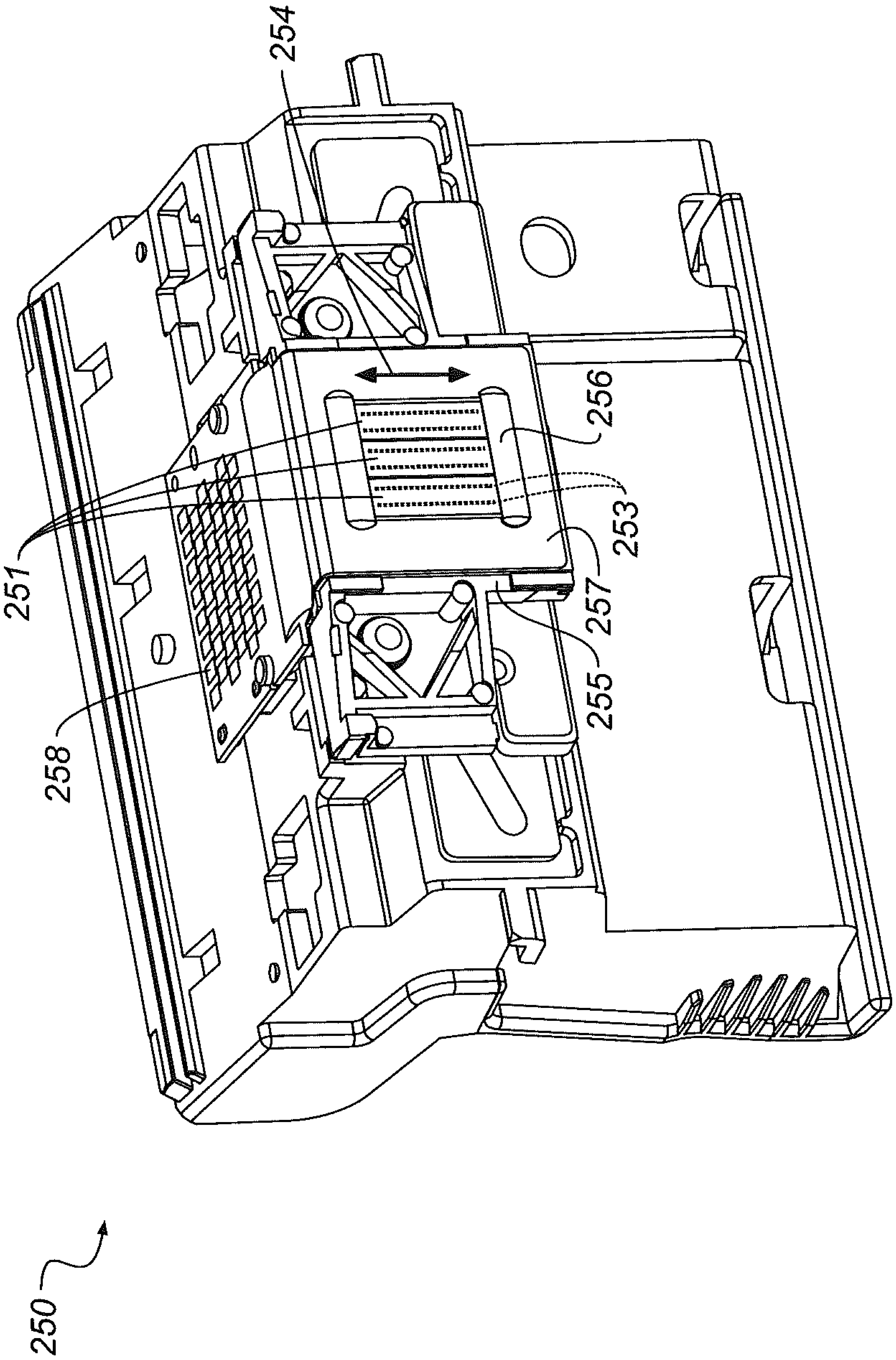

FIG. 2

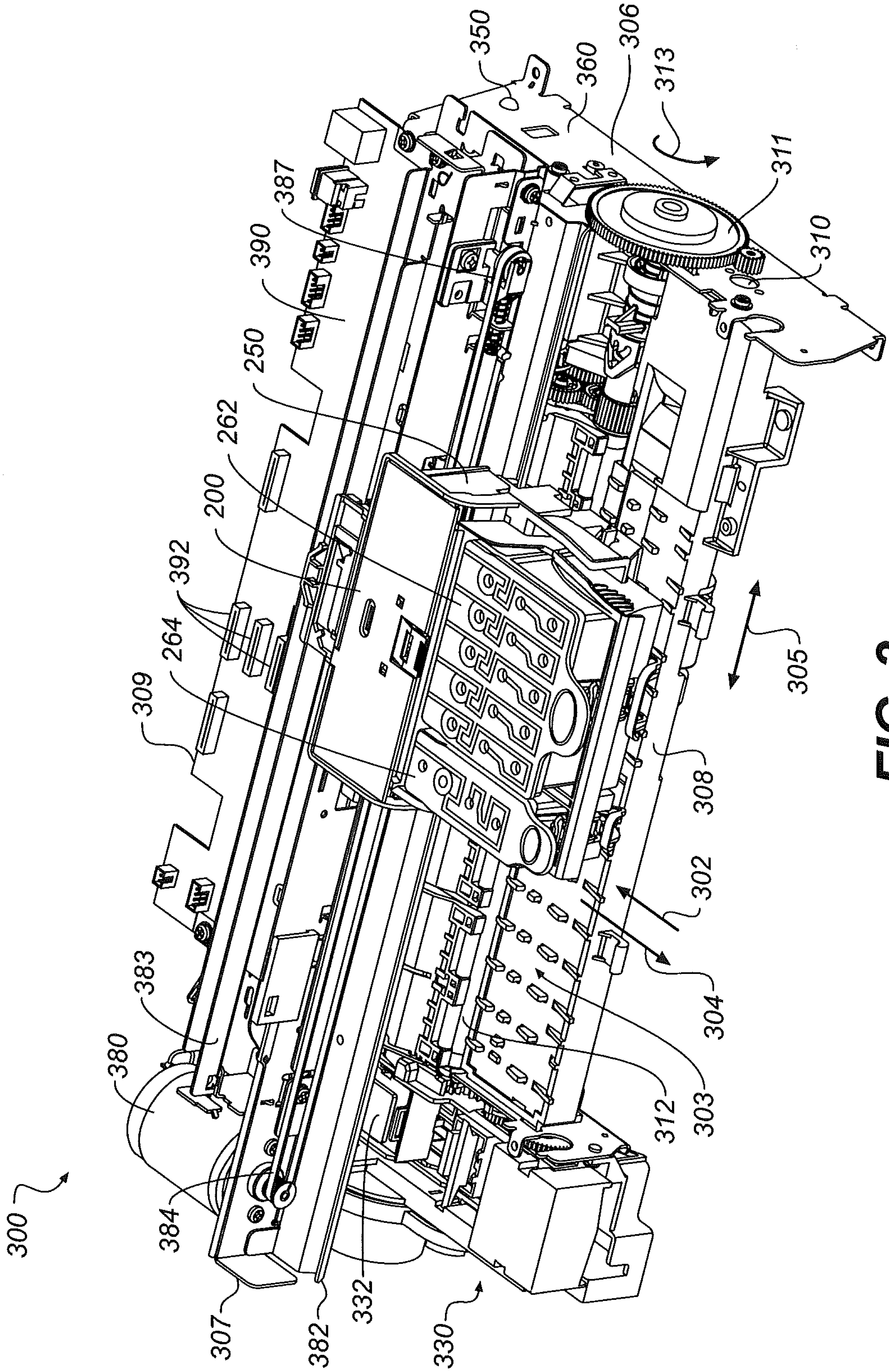
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FIG. 3

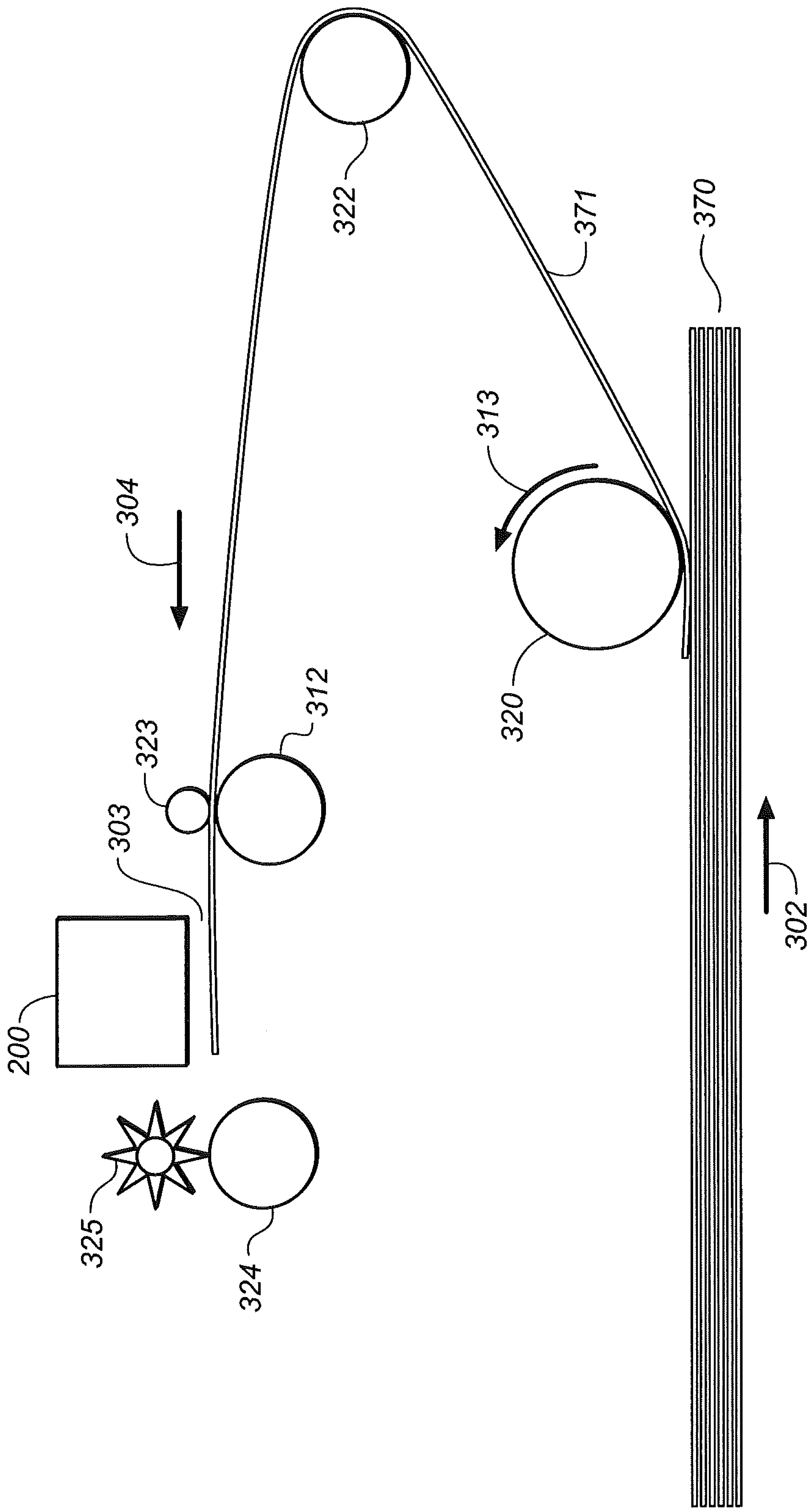

FIG. 4

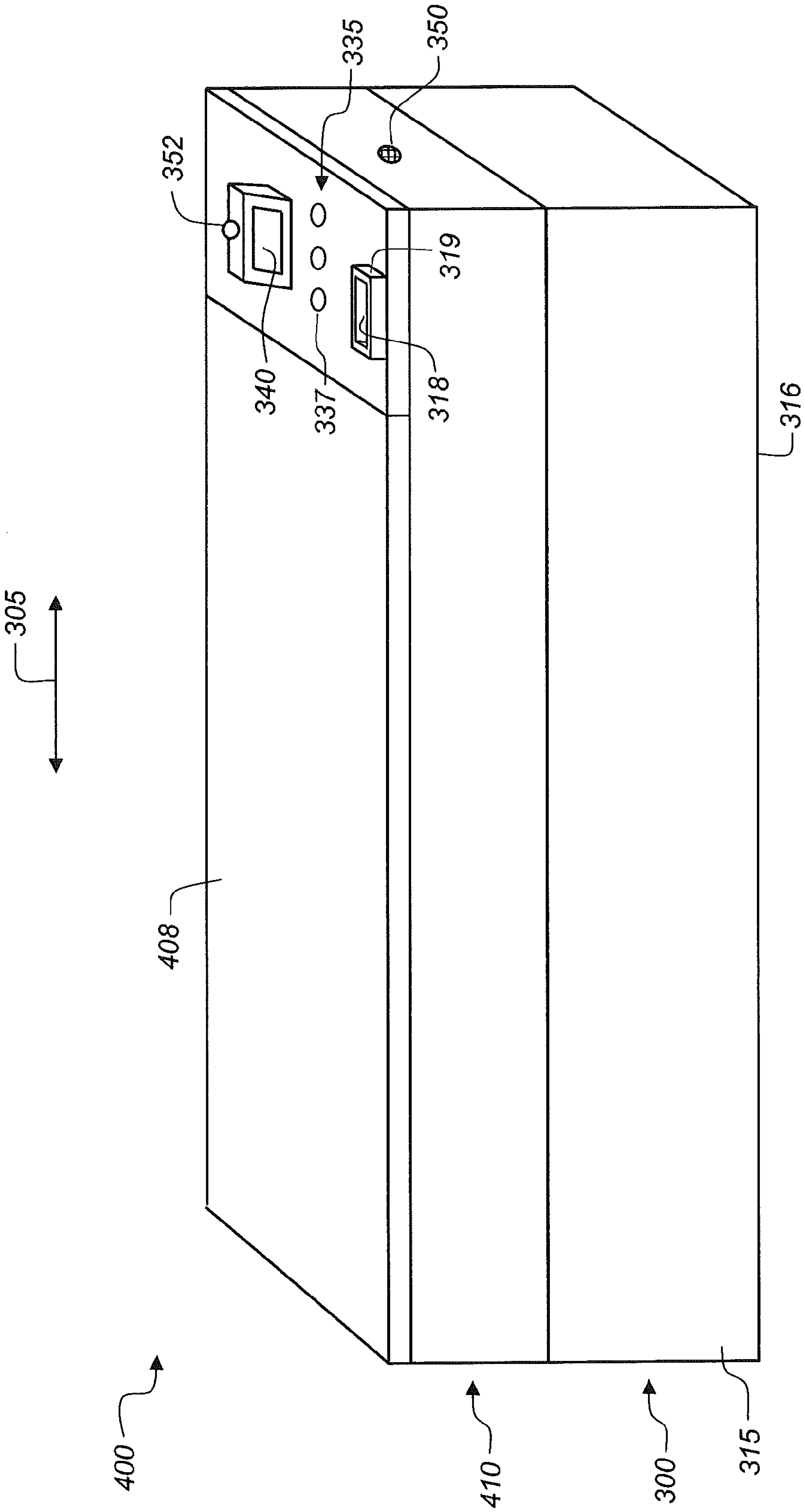

FIG. 5

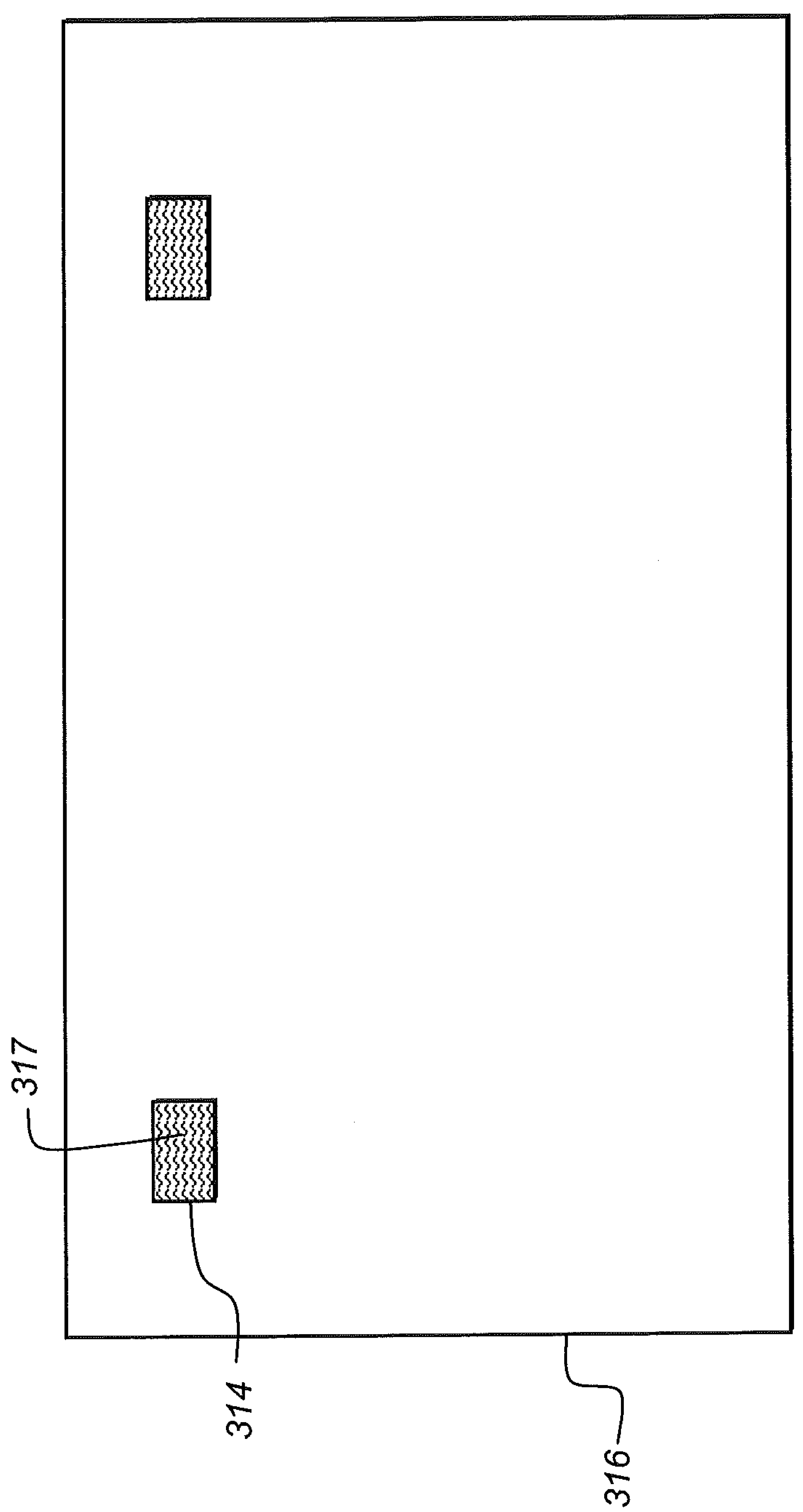

FIG. 6

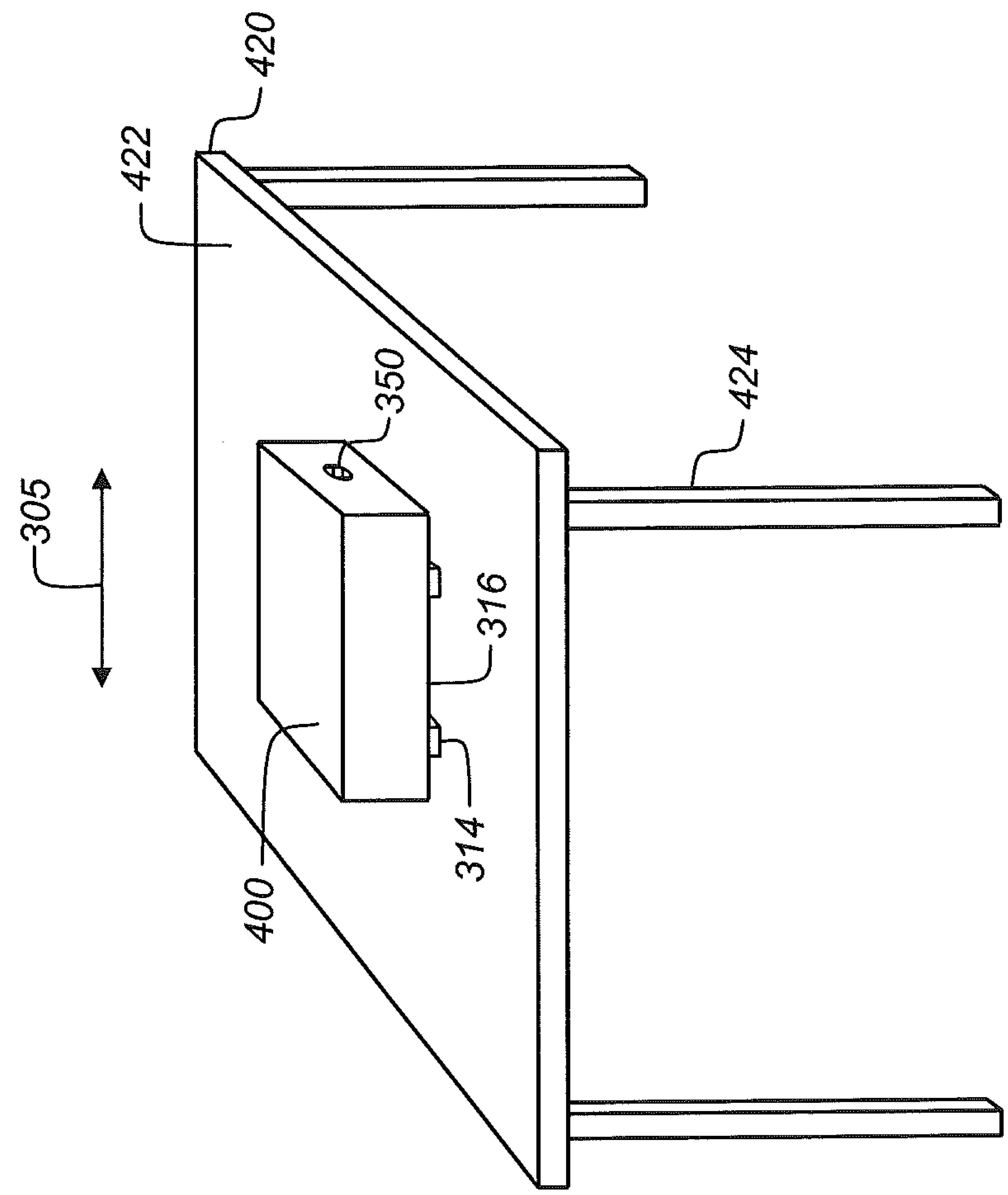

FIG. 7

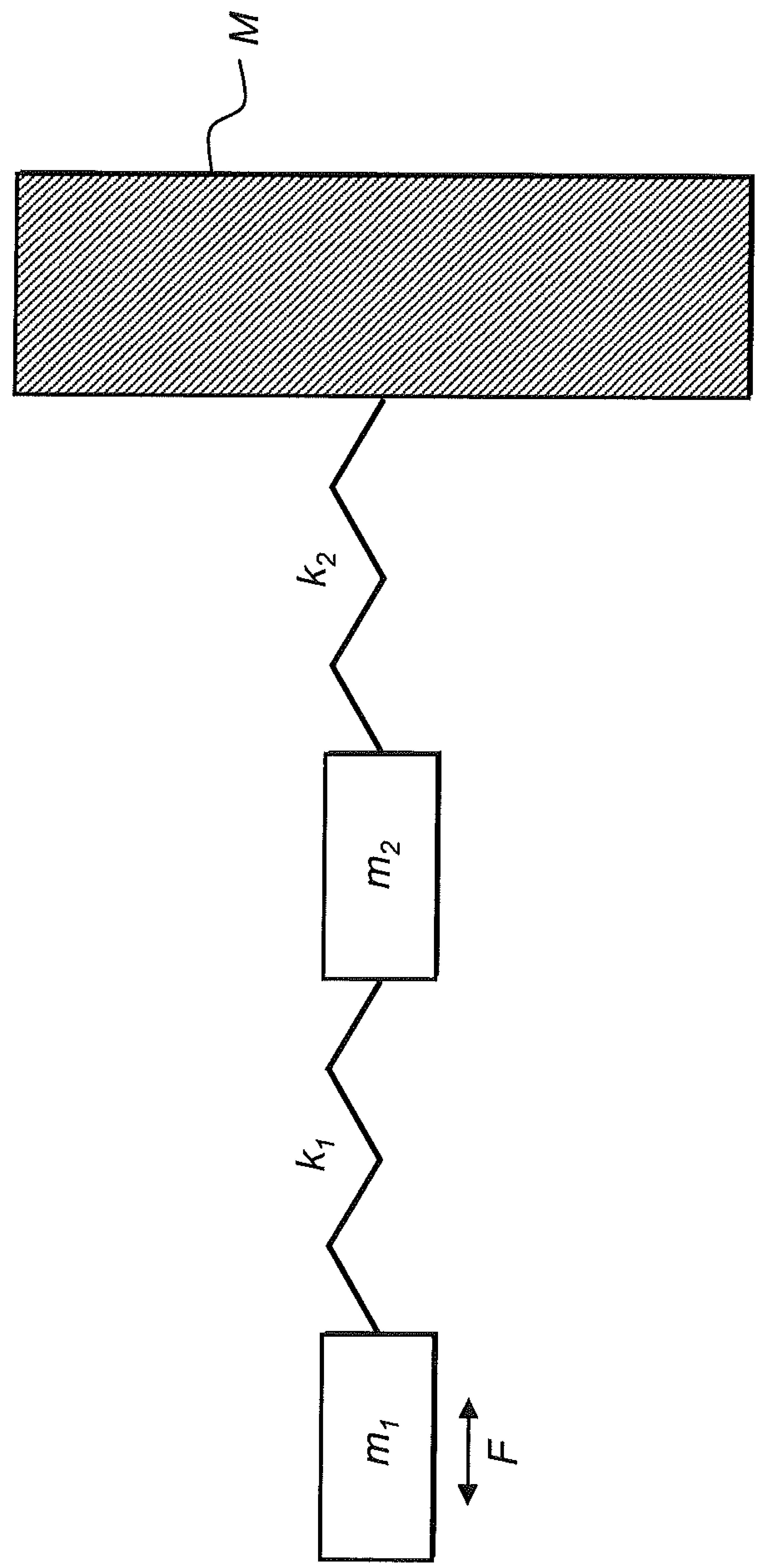

FIG. 8

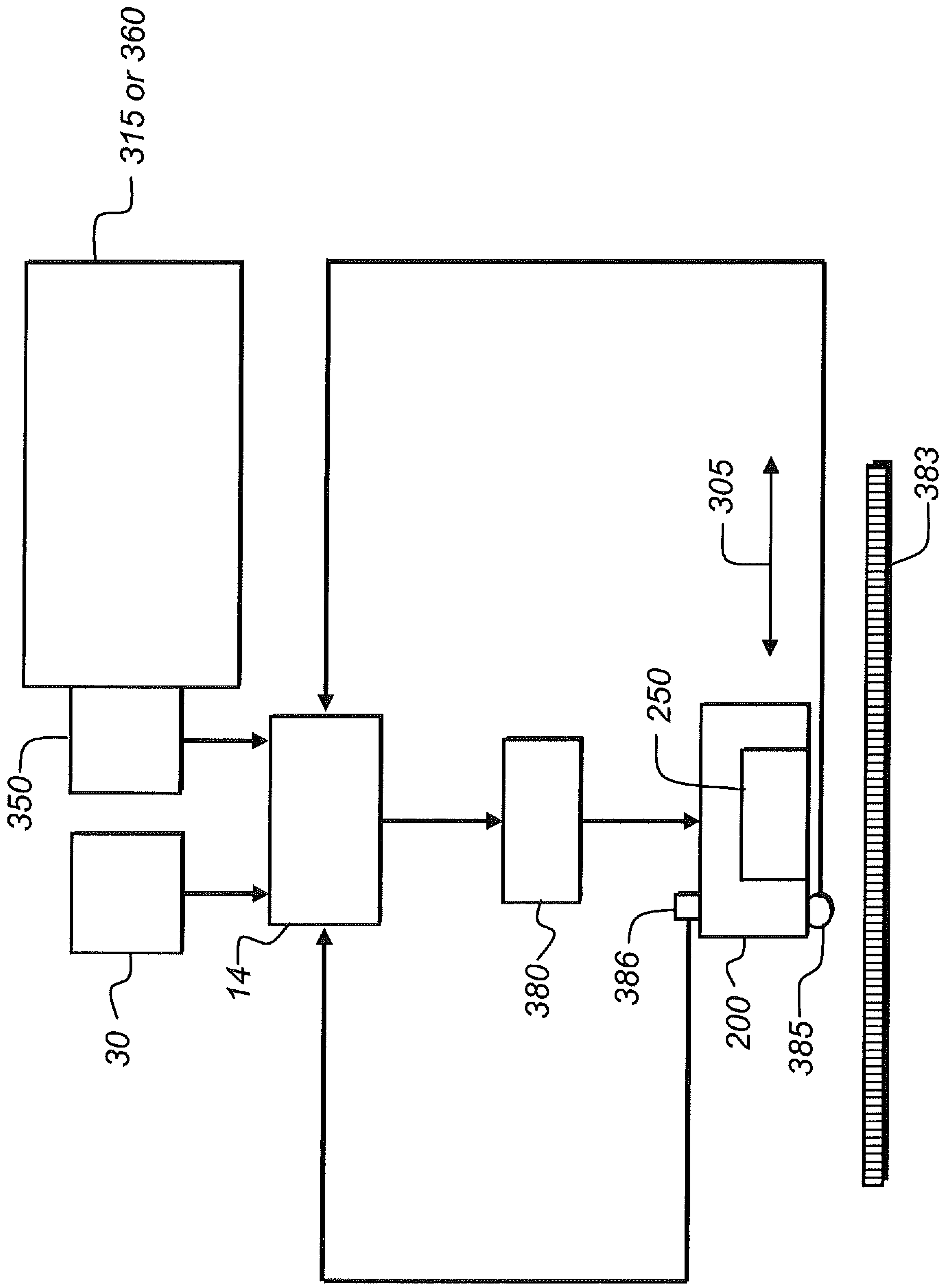

FIG. 9

ADAPTIVE MOTION CONTROL FOR CARRIAGE PRINTER

CROSS REFERENCE TO RELATED APPLICATION

Reference is made to commonly assigned, co-pending U.S. patent application Ser. No. 13/307,523, concurrently filed herewith, entitled "Carriage Printer With Adaptive Motion Control" by Brian Price, the disclosure of which is herein incorporated by reference.

FIELD OF THE INVENTION

The present invention relates generally to motion control for a carriage printer, and more particularly to adaptive motion control of the printer within the user's environment.

BACKGROUND OF THE INVENTION

A common type of printer architecture is a carriage printer, where a printhead array of marking elements is somewhat smaller than an extent of a region of interest for printing on a recording medium and a printhead is mounted on a carriage. In a carriage printer, the recording medium is advanced a given distance along a media advance direction and then stopped. While the recording medium is stopped, the printhead is moved by the carriage in a carriage scan direction that is substantially perpendicular to the media advance direction as marks are controllably made by marking elements. After the printhead has printed a swath of an image while traversing the recording medium, the recording medium is advanced, the carriage direction of motion is reversed, and the image is formed swath by swath.

One example of a carriage printer is an inkjet printer. An inkjet printing system typically includes one or more printheads and their corresponding ink supplies. Each printhead includes an ink inlet that is connected to its ink supply and an array of drop ejectors, each ejector consisting of an ink pressurization chamber, an ejecting actuator and a nozzle through which droplets of ink are ejected. The ejecting actuator can be one of various types, including a heater that vaporizes some of the ink in a pressurization chamber in order to propel a droplet out of an orifice, or a piezoelectric device which changes the wall geometry of the chamber in order to generate a pressure wave that ejects a droplet. The droplets are typically directed toward paper or other recording medium in order to produce an image according to image data that is converted into electronic firing pulses for the drop ejectors as the printhead is moved relative to the recording medium.

Faster printing throughput can be achieved in the carriage printer by printing at a faster carriage speed. However, the distance (d) required to accelerate from a stopped position to a constant velocity v_c (and similarly to decelerate to a stopped position) is given by $d=v_c^2/2a$, where (a) is the acceleration. Therefore, as the carriage velocity is increased, it is desirable to increase the acceleration so that the width of the acceleration region beyond the print region doesn't increase to unacceptable levels, requiring that the printer be significantly wider than the print media. Such acceleration and deceleration can cause significant forces, particularly for carriages having a large mass, which can tend to cause the carriage printer to shake.

Many inkjet printers carry their ink supplies on the carriage. It is desirable for the ink supplies of the various colors (typically cyan, magenta, yellow and black, and sometimes other inks as well) be large enough for printing of at least several hundred pages, so that the user is not required to replace ink tanks too frequently. However, the more ink that is carried by the carriage, the higher the carriage mass is, and consequently the higher the forces are that result when the carriage accelerates and decelerates.

Different users of printers have different work environments that are not always predicatable. Many users operate their printers on a sturdy work surface such as a massive desk. Others operate their printers on a surface, such as a file cabinet, that is not generally intended as a support surface for a printer. Still other users operate their printer on whatever type of table they happen to have. For example, some users operate their printers on lightweight card tables having foldable legs. A relatively flimsy work surface such as this can be more dramatically impacted by carriage forces than a sturdy support structure. The resulting shaking of the work surface can be noisy and annoying, and can result in damage. For example, if the user has a laptop computer, a carriage printer, some documents and a glass of water on a card table that is caused to shake by carriage motion, water could slosh out of the glass and onto the documents or laptop computer and damage them.

Printer manufacturers are thus typically constrained by the unpredicatability of the user's environment and make trade-offs between slowing down printing throughput by reducing carriage acceleration and limiting the amount of ink that is moved by the carriage. What is needed is a carriage printer and a method of operating the printer that is able to monitor its motion within the user's environment and adjust its carriage motion control accordingly.

SUMMARY OF THE INVENTION

The present invention is directed to overcoming one or more of the problems set forth above. Briefly summarized, according to one aspect of the invention, the invention resides in a method of adaptively controlling motion of a carriage in a carriage printer within a user's environment, the method comprising: controlling a motor to move a carriage of a carriage printer within a user's environment according to a first motor control profile; acquiring data relative to a motion of the carriage printer as the carriage is moved according to the first motor control profile; analyzing the acquired data relative to the motion of the carriage printer corresponding to the carriage being moved according to the first motor control profile; and controlling the motor to move the carriage of the carriage printer according to a second motor control profile.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic representation of an inkjet printer system;

FIG. **2** is a perspective of a portion of a printhead;

FIG. **3** is a perspective of a portion of a carriage printer including a motion detector according to an embodiment;

FIG. **4** is a schematic side view of an exemplary paper path in a carriage printer;

FIG. **5** is a perspective of a multifunction printer including a motion detector according to an embodiment;

FIG. **6** is a bottom view of a base of a printer;

FIG. **7** is a perspective of a printer including a motion detector according to an embodiment and a support unit for the printer;

FIG. **8** is a schematic diagram of a mass driven by a periodic force in a system of coupled oscillators; and

FIG. **9** is a block diagram of a motion control system for the carriage of a carriage printer according to an embodiment.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1**, a schematic representation of an inkjet printer system **10** is shown, for its usefulness with the present invention and is fully described in U.S. Pat. No. 7,350,902, and is incorporated by reference herein in its entirety. Inkjet printer system **10** includes an image data source **12**, which provides data signals that are interpreted by a controller **14** as being commands to eject drops. Controller **14** includes an image processing unit **15** for rendering images for printing, and outputs signals to an electrical pulse source **16** of electrical energy pulses that are inputted to an inkjet printhead **100**, which includes at least one inkjet printhead die **110**.

In the example shown in FIG. **1**, there are two nozzle arrays **120**, **130** disposed at a surface of inkjet printhead die **110**. Nozzles **121** in the first nozzle array **120** have a larger opening area than nozzles **131** in the second nozzle array **130**. In this example, each of the two nozzle arrays **120**, **130** has two staggered rows of nozzles, each row having a nozzle density of 600 per inch. The effective nozzle density then in each array is 1200 per inch (i.e. d=1/1200 inch in FIG. **1**). If pixels on a recording medium **20** were sequentially numbered along a paper advance direction, the nozzles from one row of an array would print the odd numbered pixels, while the nozzles from the other row of the array would print the even numbered pixels.

In fluid communication with each nozzle array **120**, **130** is a corresponding ink delivery pathway **122**, **132**. Ink delivery pathway **122** is in fluid communication with the first nozzle array **120**, and ink delivery pathway **132** is in fluid communication with the second nozzle array **130**. Portions of ink delivery pathways **122** and **132** are shown in FIG. **1** as openings through printhead die substrate **111**. One or more inkjet printhead die **110** will be included in inkjet printhead **100**, but for greater clarity only one inkjet printhead die **110** is shown in FIG. **1**. The printhead die **110** are arranged on a support member as discussed below relative to FIG. **2**. In FIG. **1**, first ink source **18** supplies ink to first nozzle array **120** via ink delivery pathway **122**, and a second ink source **19** supplies ink to second nozzle array **130** via ink delivery pathway **132**. Although distinct ink sources **18** and **19** are shown, in some applications it can be beneficial to have a single ink source supplying ink to both the first nozzle array **120** and the second nozzle array **130** via ink delivery pathways **122** and **132** respectively. Also, in some embodiments, fewer than two or more than two nozzle arrays **120**, **130** can be included on printhead die **110**. In some embodiments, all nozzles on inkjet printhead die **110** can be the same size, rather than having multiple sized nozzles on inkjet printhead die **110**.

Not shown in FIG. **1**, are the drop forming mechanisms associated with the nozzles. Drop forming mechanisms can be of a variety of types, some of which include a heating element to vaporize a portion of ink and thereby cause ejection of a droplet, or a piezoelectric transducer to constrict the volume of a fluid chamber and thereby cause ejection, or an actuator which is made to move (for example, by heating a bi-layer element) and thereby cause ejection. In any case, electrical pulses from electrical pulse source **16** are sent to the various drop ejectors according to the desired deposition pattern. In the example of FIG. **1**, droplets **181** ejected from the first nozzle array **120** are larger than droplets **182** ejected from the second nozzle array **130**, due to the larger nozzle opening area. Typically other aspects of the drop forming mechanisms (not shown) associated respectively with nozzle arrays **120** and **130** are also sized differently in order to optimize the drop ejection process for the different sized drops. During operation, droplets of ink are deposited on a recording medium **20**.

FIG. **2** shows a perspective view of a portion of a printhead **250**, which is an example of the inkjet printhead **100**. Printhead **250** includes three printhead die **251** (similar to printhead die **110** in FIG. **1**) that are affixed to a mounting substrate **255**. The surface of the mounting substrate **255** to which the printhead die **250** are bonded is also called a face **252** of the printhead (see FIG. **10**). Each printhead die **251** contains two nozzle arrays **253**, so that printhead **250** contains six nozzle arrays **253** altogether. The six nozzle arrays **253** in this example are each be connected to ink sources (not shown in FIG. **2**), such as cyan, magenta, yellow, text black, photo black, and protective fluid. Each of the six nozzle arrays **253** is disposed along nozzle array direction **254**, and the length of each nozzle array along the nozzle array direction **254** is typically on the order of 1 inch or less. Typical lengths of recording media are 6 inches for photographic prints (4 inches by 6 inches) or 11 inches for paper (8.5 by 11 inches). Thus, in order to print a full image, a number of swaths are successively printed while moving printhead **250** across the recording medium **20**. Following the printing of a swath, the recording medium **20** is advanced along a media advance direction that is substantially parallel to nozzle array direction **254**.

Also shown in FIG. **2** is a flexible circuit **257** to which the printhead die **251** are electrically interconnected, for example, by wire bonding or TAB bonding. Flexible circuit **257** is also adhered to mounting substrate **255**, and surrounds the printhead die **250**. The interconnections are covered by an encapsulant **256** to protect them. Flexible circuit **257** bends around the side of printhead **250** and connects to a connector board **258** on rear wall **275**. When printhead **250** is mounted into the carriage **200**, connector board **258** is electrically connected to a connector **244** on the carriage **200**, so that electrical signals can be transmitted to the printhead die **251**.

FIG. **3** shows a portion of a desktop carriage printer. Some of the parts of the printer have been hidden in the view shown in FIG. **3** so that other parts can be more clearly seen. A printer chassis **300** has a platen **301** in print region **303** across which carriage **200** is moved back and forth in a carriage scan direction **305** between a right side **306** and a left side **307** of printer chassis **300**, while drops are ejected from printhead die **251** (not shown in FIG. **3**) on printhead **250** that is mounted on carriage **200**. Paper or other recording medium is held substantially flat against platen **301**. A Carriage motor **380** moves a belt **384** to move carriage **200** along carriage a guide rail **382**. An encoder sensor (not shown) is mounted on carriage **200** and indicates carriage location relative to a linear encoder **383**.

Carriage motor **380** and a mount for a pulley **387** at the opposite end of belt **384** are bolted to a portion of frame **360** of printer chassis **300**. Forces due to acceleration and deceleration of carriage **200** at the beginning and end of passes across print region **303** are transmitted to frame **360** through belt **384**, carriage motor **380**, and pulley **387**. According to an embodiment of the invention, a motion detector **350**, such as an accelerometer is affixed to printer frame **360** for detecting motion of the carriage printer, typically along carriage scan direction **305** due to acceleration and deceleration of carriage **200**. The magnitude of the acceleration and deceleration applied to the carriage **200** is typically in a range of 1 g to 3 g, where g is the strength of earth's gravitational field at its surface, approximately 9.81 m/sec^2.

The mounting orientation of printhead **250** is rotated relative to the view in FIG. **2**, so that the printhead die **251** are located at the bottom side of printhead **250**, the droplets of ink being ejected downward onto the recording medium in print region **303** in the view of FIG. **3**. A multi-chamber ink tank **262**, in this example, contains five ink sources: cyan, magenta, yellow, photo black and colorless protective fluid; while a single-chamber ink tank **264** contains the ink source for text black. Ink tanks **262** and **264** can include electrical contacts (not shown) for data storage devices, for example, to track ink usage. In other arrangements, rather than having a multi-chamber ink tank to hold several ink sources, all ink sources are held in individual single chamber ink tanks. In any case, the ink sources in the configuration shown in FIG. **3** are mounted on printhead **250** which is moved by carriage **200**, so the mass of the ink contributes to the mass that is accelerated and decelerated at the ends of printing passes.

Paper or other recording medium (sometimes generically referred to as paper or media herein) is loaded along paper load entry direction **302** toward the front of printer chassis **308**. A variety of rollers are used to advance the medium through the printer as shown schematically in the side view of FIG. **4**. In this example, a pick-up roller **320** moves the top piece or sheet **371** of a stack **370** of paper or other recording medium in the direction of arrow, paper load entry direction **302**. A turn roller **322** acts to move the paper around a C-shaped path (in cooperation with a curved rear wall surface) so that the paper continues to advance along a media advance direction **304** from the rear **309** of the printer chassis (with reference also to FIG. **3**). The paper is then moved by a feed roller **312** and idler roller(s) **323** to advance across print region **303** (platen not shown), and from there to a discharge roller **324** and star wheel(s) **325** so that printed paper exits along media advance direction **304**. Feed roller **312** includes a feed roller shaft along its axis, and feed roller gear **311** is mounted on the feed roller shaft. Feed roller **312** can include a separate roller mounted on the feed roller shaft, or can include a thin high friction coating on the feed roller shaft. A rotary encoder (not shown) can be coaxially mounted on the feed roller shaft in order to monitor the angular rotation of the feed roller.

The motor that powers the paper advance rollers is not shown in FIG. **3**, but the hole **310** at the right side of the printer chassis **306** is where the motor gear (not shown) protrudes through in order to engage feed roller gear **311**, as well as the gear for the discharge roller (not shown). For normal paper pick-up and feeding, it is desired that all rollers rotate in forward rotation direction **313**. Toward the left side of the printer chassis **307**, in the example of FIG. **3**, is a maintenance station **330** including a cap **332** and a wiper (not shown).

Toward the rear of the printer chassis **309**, in this example, is located an electronics board **390**, which includes cable connectors **392** for communicating via cables (not shown) to the printhead carriage **200** and from there to the printhead **250**. Also on the electronics board **390** are typically included motor controllers for the carriage motor **380** and for the paper advance motor, a processor and/or other control electronics (shown schematically as controller **14** and image processing unit **15** in FIG. **1**) for controlling the printing process, a clock and an optional connector for a cable to a host computer.

FIG. **5** shows a multifunction printer **400** according to an embodiment of the invention. The multifunction printer **400** includes a printing mechanism for printing images, such as a carriage printer chassis **300** (FIG. **3**), as well as a scanning apparatus **410** for scanning documents or other items. The scanning apparatus **410** includes a lid **408** that is pivotally attached. A housing **315** is attached to the printer frame **360** (FIG. **3**) to provide an external portion of the multifunction printer **400**. The housing **315** can include a portion that encloses the printer chassis **300** and a portion that encloses the scanning apparatus **410**. In other embodiments (not shown) there is no scanning apparatus **410**, and the housing **315** only encloses the carriage printer chassis **300**. The multifunction printer **400** includes a display **340** and a control panel **335** having control buttons **337** for controlling the operation. Control buttons **337** can be separate from the display **340**, or in the case of a touch screen, one or more control buttons can be integrated into the display **340**.

Several different alternatives are shown in FIG. **5** for providing a motion detector **350**. Motion detector **350** can include an accelerometer affixed to the housing **315**. Alternatively, the motion detector **350** can include an optical sensor **352**, such as a camera. In this example, optical sensor **352** is attached to the display **340** which is affixed to the housing **315**. The motion detector **350** can be dedicated to the single function of detecting motion of the carriage printer. Alternatively, as in the case of a camera, the motion detector **350** can have additional purposes such as taking portraits, as disclosed in U.S. patent application Ser. No. 13/159,527 filed Jun. 14, 2011. The motion detector **350** can even be an external device, such as a mobile communication device (not shown) that is detachably mountable on the housing **315**. Some smart phones that are currently commercially available include both a camera and one or more accelerometers. In some embodiments, a holding receptacle **318** is provided on the housing **315** in which the detachably mountable device is held. Walls **319** around the holding receptacle **318**, or a friction pad (not shown) within the holding receptacle **318**, or other ways of securing the external device can be provided in order to constrain the external device including the motion detector(s) to move along with the housing **315**.

Generally only one motion detector **350** is needed, whether on the frame **360** (FIG. **3**) or on the housing **315** (FIG. **5**), and whether an accelerometer or an optical sensor **352**. In any case, the motion detector **350** is typically mounted in such a way that it can detect motion of the carriage printer along a carriage scan direction **305** as a result of carriage acceleration and deceleration. For example, the optical sensor **352** such as a camera can take multiple sequential views of a stationary object such as a wall or a ceiling and monitor the apparent motion of a feature on that object as the optical sensor **352** moves with the carriage printer. The optical sensor **352** should have capability for acquiring images in rapid succession. Commercially available smart phones, for example, presently have the capability of acquiring images at **30** frames per second with VGA quality photos or HD video.

A base **316** of the multifunction printer **400** sits on a support unit in the user's environment such as a desktop or table during operation. As shown in the schematic bottom view of FIG. **6**, the base **316** typically includes at least one pad **314** that is configured to contact a support surface when the printer is in its operating orientation. The pad **314**, which can be an elastomeric pad for example, typically has a high friction contact surface **317**. Generally contact surface **317** has a coefficient of friction that is higher than a coefficient of friction of the rest of the base **316**, which is typically an injection molded hard plastic.

FIG. **7** shows a perspective of the multifunction printer **400** on a table **420**. The high friction pads **314** on the base **316** are in contact with a support surface **422** of the table **420**. The weight of multifunction printer **400** pressing down on the high friction pads **314** causes the motion of the multifunction printer **400** to be coupled to the support surface **422**. For the case of a sturdy and massive table or desk or other such sturdy and massive support unit, the forces due to carriage acceleration and deceleration along the carriage scan direction **305** do not result in significant movement of the support unit. However, if as in the example of FIG. **7**, the support unit is a lightweight table with somewhat spindly legs **424**, as in a typical card table, carriage acceleration and deceleration forces along carriage scan direction **305** can result in significant shaking of the table **420**. If, as in embodiments of the present invention, the multifunction printer **400** includes the motion detector **350** to detect movement of the printer due to carriage acceleration and deceleration forces, the motion of the carriage can be adapted within the user's environment to keep such movement of the printer and the user's work surface from being excessive.

Shaking of a support unit that is induced by carriage acceleration and deceleration forces in a carriage printer is related to the motion of a mass m_1 driven by a periodic force F in a system of coupled oscillators, as illustrated in FIG. **8**. Two masses m_1 and m_2 are coupled together and to a more massive object M by springs having spring constants k_1 and k_2. There are also frictional losses regarding the motion of each of the masses. A driven mass in a system of coupled oscillators often excites resonance modes, depending on characteristics of the system including the masses, the spring constants, and how the mass is driven. It is possible to suppress resonance modes by the manner in which the mass is driven. Two driving modes can result in similar motion of m_1, where the first driving mode excites resonant motion of m_2 and the second driving mode excites significantly less amplitude of motion of m_2. In this analogous problem, the driven mass m_1 is similar to the carriage, while the coupled mass m_2 is similar to the printer and support surface that the printer sits on. Mass M can be the floor that the support unit sits on. The driving force F and spring k_1 are similar to the carriage motor **380** and its belt **384** and pulley **387** (FIG. **3**). Spring k_2 includes the high friction pads **314** on base **316** (FIG. **6**) and legs **424** and the joints between the legs and the table's support surface **422** (FIG. **7**). In order to suppress resonance, the driving force F can be subdivided into a sequence of steps that provide a close approximation to the desired motion of mass m_1, but do not excite resonance of mass m_2.

FIG. **9** shows a block diagram of the motion control system for the carriage **200**. The carriage **200** moves the printhead **250** back and forth along the carriage scan direction **305**. A linear encoder **383** is disposed along the carriage scan direction **305**. An encoder sensor **385** is mounted on the carriage **200** and senses the regularly spaced black and white transitions on the linear encoder **383**. The encoder sensor **385** sends signals corresponding to the black and white transitions to the controller **14**. The controller **14** controls the carriage motor **380** to rotate in forward or reverse directions by amounts to move the carriage **200** at a speed and direction as needed.

The controller **14** can include a digital servo that uses error-sensing feedback to control carriage motion in various motion control modes. Carriage position is interpreted by the controller **14** based on the signals sent by the encoder sensor **385**. Any difference between the actual and desired position (an error signal) is amplified and used to drive the carriage motor **380** in the direction necessary to reduce or eliminate the error. In addition to controlling carriage position, the digital servo can determine and control carriage velocity by monitoring carriage position by the signals from the encoder sensor **385** as a function of time, based on signals from a clock **30**. Differences between actual and desired velocity provide a second error signal that is amplified to drive the carriage motor **380** in such a way as to provide a uniform desired velocity in the print region **303**, for example. Acceleration and deceleration of the carriage **200** is similarly controlled according to the desired rate of change of velocity with time.

The details of how the acceleration and deceleration are applied during different time intervals will influence whether resonant motion of the carriage printer and its support unit in the user's environment will be excited or not. According to embodiments of the present invention, the controller **14** is configured to control carriage motor **380** using a motor control profile that is adaptable based on motion of the carriage printer, as detected by the motion detector **350**.

Embodiments of methods of adaptively controlling motion of a carriage in a carriage printer within a user's environment are next described. The controller **14** controls the carriage motor **380** to move the carriage **200** within the user's environment according to a first motor control profile. Data is acquired by the motion detector **350** relative to motion of the housing **315** or the frame **360** of the carriage printer as the carriage **200** is moved according to the first motor control profile. Motion of the housing **315** or frame **360** will be referred to herein as motion of the carriage printer, as distinguished from motion of the carriage **200** which is detected by encoder sensor **385** and linear encoder **383**. The acquired data relative to motion of the carriage printer as the carriage **200** is moved according to the first motor control profile is analyzed. The controller **14** then controls the carriage motor **380** to move the carriage **200** according to a second motor control profile. Data is acquired and analyzed relative to the motion of the carriage printer corresponding to the carriage **200** being moved according to the second motor profile. If motion of the carriage printer corresponding to the first or second motor profile is sufficiently low, no further motor control profiles need to be tested. However, if motion of the carriage printer is still excessive, the controller **14** then controls carriage motor **380** to move the carriage **200** according to a third motor control profile and the motion data is acquired and analyzed. The process can continue iteratively until a motor control profile is identified that results in a reduced amount of motion of the carriage printer compared with an amount of motion of the carriage printer resulting from the first motor control profile, and such that the amount of motion of the carriage printer with the identified motor control profile is acceptable.

Controlling of the carriage motor **380** with a first motor control profile, a second motor control profile, and further motor control profile iterations can be done according to a predetermined series of motor control profiles, with the selected motor control profile being the one having the least amount of motion detected by the motion detector. Alternatively, successive motor control profiles can be selected based on the analyzed motion data corresponding to the previous motor control profile(s). For example, the printer manufacturer can test the motion of the carriage printer as a function of motor control profiles with the printer mounted on a variety of types of support units that might typically be used in a user's environment. Motor control profile selection guidance can then be provided, for example in a look-up table, to help select a second motor control profile based on the analyzed data relative to the motion of the carriage printer corresponding to the carriage **200** being moved according to the first motor control profile while in the user's environment. Such a guided process can typically arrive at a satisfactory level of printer motion with fewer iterative steps.

Controlling the carriage motor **380** to move the carriage **200** according to the first motor control profile typically includes accelerating the carriage **200** to move in a first direction and decelerating the carriage **200** to a stop. In some embodiments, controlling the carriage motor **380** to move carriage **200** according to the first motor profile further includes accelerating carriage **200** to move in a second direction that is opposite the first direction, and decelerating carriage **200** to a stop, thereby completing a carriage motion cycle. In other embodiments, controlling carriage motor **380** to move carriage **200** according to the first motor control profile further includes accelerating and decelerating carriage **200** for a plurality of carriage motion cycles. The second motor control profile is similar to the first motor control profile in terms of the overall motion of carriage **200**, but is different in the details of how acceleration and deceleration is done, for example how it is divided into different time intervals. In some embodiments a travel time of the carriage **200** for a second motor control profile that is less susceptible to inducing resonant motion of the printer and support unit can be substantially the same as a travel time of the carriage **200** corresponding to a first motor control profile that is more susceptible to inducing resonant motion. In other embodiments the travel time for the second motor control profile is longer than that for the first motor control profile, but not objectionably longer. Because the printer manufacturer can depend upon adapting the motion control to the user's environment, the default magnitudes of acceleration and deceleration can be made greater, and reduced as required for users having a support unit that is less massive and sturdy. In such embodiments, a message can be displayed to the user that higher printing throughput can be provided if the user moves the printer to a more massive and sturdy support unit.

The method of adaptively controlling motion of a carriage in a carriage printer within a user's environment is typically implemented for a new printer when it is first set up by the user. Optionally, it would be repeated if the motion detector **350** (e.g. accelerometer or optical sensor **352**) detects a motion, or change of surroundings, or a change in the motion the carriage printer in response to the selected motor control profile that could indicate a change in the support unit. In addition, because the forces due to acceleration and deceleration of the carriage **200** also depend upon the mass of the carriage **200**, in some embodiments the mass of the carriage **200** is monitored by a carriage mass monitor **386** and the mass is also used as an input to the controller **14** in selecting motor control profiles, as indicated in FIG. **9**. One type of carriage mass monitor **386** is an ink level sensor for each of the ink supplies on the carriage **200**. Ink level can be sensed directly using optical means for example in some embodiments, or it can be sensed indirectly by monitoring the amount of ink that has been used in printing and in maintenance operations. Information corresponding to the mass of the carriage when the ink supplies are full would be provided to the controller **14**. Then as lower ink levels are sensed, a mass corresponding to the amount of used ink would be subtracted.

Data analysis of the motion of the carriage printer acquired by the motion detector **350** can include analytical methods such as performing a fast Fourier transform of the acquired data in order to provide a vibration frequency spectrum. Such a vibration frequency spectrum can then be used to identify characteristics of the resonant motion in order to guide selection of subsequent motor control profiles.

Some carriage printers have sufficient processing power in a microprocessor included in the controller **14** to analyze data from the motion detector **350** and to provide instructions for adapting the motor control profile. In other embodiments, an external computer to which the carriage printer is connected (through cables or through wireless connection) includes software to analyze data acquired from the motion detector **350** and to provide instructions to the controller **14** for adapting the motor control profile. Such an external computer can be a host computer for the printer, or it can be remotely connected through a network to the carriage printer. For embodiments using a mobile communication device as the motion detector **350**, acquiring data relative to motion of the carriage printer can include transmission of data from the mobile communication device, either directly to the controller **14** of the printer, or to a remote server. In the latter case, the mobile communication device can include an application (or "app") for acquiring the data, transmitting it to a remote server, receiving instructions from the remote server after the server has analyzed the acquired data, and transmitting the instructions to controller **14**.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention. For example, although the examples were described in terms of multifunction inkjet printers, use of the invention for a single function carriage printer, whether inkjet or some other marking technology, is also contemplated.

PARTS LIST

10 Inkjet printer system
12 Image data source
14 Controller
15 Image processing unit
16 Electrical pulse source
18 First ink source
19 Second ink source
20 Recording medium
30 Clock
100 Inkjet printhead
110 Inkjet printhead die
111 Substrate
120 First nozzle array
121 Nozzle(s)
122 Ink delivery pathway (for first nozzle array)
130 Second nozzle array
131 Nozzle(s)
132 Ink delivery pathway (for second nozzle array)
181 Droplet(s) (ejected from first nozzle array)
182 Droplet(s) (ejected from second nozzle array)
200 Carriage
250 Printhead
251 Printhead die
252 Printhead face
253 Nozzle array
254 Nozzle array direction
255 Mounting substrate
256 Encapsulant
257 Flexible circuit
258 Connector board
262 Multichamber ink tank
264 Single chamber ink tank
275 Rear Wall
300 Printer chassis
301 Platen
302 Paper load entry direction
303 Print region
304 Media advance direction
305 Carriage scan direction
306 Right side of printer chassis
307 Left side of printer chassis
308 Front of printer chassis
309 Rear of printer chassis
310 Hole (for paper advance motor drive gear)
311 Feed roller gear

312 Feed roller
313 Forward rotation direction (of feed roller)
314 Pad
315 Housing
316 Base
317 Contact surface
318 Holding receptacle
319 Wall
320 Pick-up roller
322 Turn roller
323 Idler roller
324 Discharge roller
325 Star wheel(s)
330 Maintenance station
332 Cap
335 Control panel
337 Control button
340 Display
350 Motion detector
352 Optical sensor
360 Frame
370 Stack of media
371 Top piece of medium
380 Carriage motor
382 Carriage guide rail
383 Linear encoder
384 Belt
385 Encoder sensor
386 Carriage mass monitor
387 Pulley
390 Printer electronics board
392 Cable connectors
400 Multifunction printer
408 Lid
410 Scanning apparatus
420 Table
422 Support surface
424 Leg

The invention claimed is:

1. A method of adaptively controlling motion of a carriage disposed within a housing in a carriage printer, the method comprising:

controlling a motor to move the carriage back and forth along a carriage guide rail disposed within the housing of a carriage printer according to a first motor control profile;

acquiring data relative to a motion of the carriage printer as the carriage is moved according to the first motor control profile;

analyzing the acquired data relative to the motion of the carriage printer corresponding to the carriage being moved according to the first motor control profile; and

controlling the motor to move the carriage of the carriage printer according to a second motor control profile, which minimizes an amount of motion of the carriage printer caused by the carriage moving back and forth along the carriage guide rail.

2. The method according to claim **1**, wherein the second motor control profile results in a reduced amount of motion of the carriage printer compared with an amount of motion of the carriage printer resulting from the first motor control profile.

3. The method according to claim **1** further comprising:

acquiring data relative to a motion of the carriage printer as the carriage is moved according to the second motor control profile;

analyzing the acquired data relative to the motion of the carriage printer corresponding to the carriage being moved according to the second motor control profile; and

when the motion of the carriage printer is determined to still be excessive, controlling the motor to move the carriage according to a third motor control profile, which further minimizes an amount of motion of the carriage printer caused by the carriage moving back and forth along the carriage guide rail.

4. The method according to claim **1** further comprising attaching a motion detector to the carriage printer to acquire data corresponding to motion of the carriage printer.

5. The method according to claim **4**, wherein attaching the motion detector to the carriage printer further includes attaching an accelerometer to the carriage printer.

6. The method according to claim **4**, wherein attaching the motion detector to the carriage printer further includes attaching an optical sensor to the carriage printer.

7. The method according to claim **4**, wherein attaching the motion detector to the carriage printer further includes detachably attaching the motion detector to the carriage printer.

8. The method according to claim **7**, wherein detachably attaching the motion detector to the carriage printer further includes temporarily mounting a mobile communication device on a housing of the carriage printer.

9. The method according to claim **8**, wherein acquiring data relative to the motion of the carriage printer further includes transmission of data from the mobile communication device.

10. The method according to claim **9**, wherein analyzing the acquired data further includes transmission of data from the mobile communication device to a remote server and using the server to analyze the acquired data.

11. The method according to claim **1** further comprising providing motor control profile selection guidance for selecting the second motor control profile based on the analyzed data relative to the motion of the carriage printer corresponding to the carriage being moved according to the first motor control profile.

12. The method according to claim **11**, wherein the motor control profile selection guidance includes a table.

13. The method according to claim **1**, wherein analyzing the acquired data includes performing a fast Fourier transform of the acquired data to provide a vibration frequency spectrum.

14. The method according to claim **1** further comprising suppressing a resonant vibration of a coupled system that includes the carriage printer and the user's support unit for the carriage printer.

15. The method according to claim **1**, wherein a travel time of the carriage corresponding to the second motor control profile is substantially the same as a travel time of the carriage corresponding to the first motor control profile.

16. The method according to claim **1**, wherein controlling the motor to move the carriage according to the first motor control profile includes:

accelerating the carriage to move in a first direction; and

decelerating the carriage to a stop.

17. The method according to claim **16**, wherein controlling the motor to move the carriage according to the first motor control profile further includes:

accelerating the carriage to move in a second direction that is opposite the first direction; and

decelerating the carriage to a stop, thereby completing a carriage motion cycle.

18. The method according to claim **17**, wherein controlling the motor to move the carriage according to the first motor control profile further includes accelerating and decelerating the carriage for a plurality of carriage motion cycles.

19. The method according to claim **1** further comprising sensing an amount of ink.

20. The method according to claim **1** further comprising displaying a message to the user regarding a support unit for the carriage printer.

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